NACA

RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

PRELIMINARY RESULTS OF A FLIGHT INVESTIGATION OF $\frac{1}{6}$-SCALE ROCKET-POWERED MODELS OF THE BELL MX-776 TO DETERMINE AILERON ROLLING EFFECTIVENESS AND TOTAL DRAG

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

An experimental investigation of the variation of aileron rolling effectiveness and total drag with Mach number has been made using $\frac{1}{6}$-scale rocket-propelled models of the Bell MX-776. Three models having constant-chordwise-thickness full-span aileron at approximate deflections of 2°, 5°, and 15° have been flown.

Positive control effectiveness over the Mach number range between approximately 0.5 and 1.2 was obtained from the models and no indication of reversal of effectiveness was encountered. The ratio of tip helix angle to aileron deflection indicated a decrease in proportional rolling effectiveness with increasing deflections in the Mach number range from approximately 0.7 to 1.0.

A drag rise of about 125 percent in the transonic region between Mach numbers of 0.85 and 1.02 followed by a gradual decrease at higher speeds was revealed.

INTRODUCTION

At the request of the Air Materiel Command, U. S. Air Force, the National Advisory Committee for Aeronautics is conducting tests of $\frac{1}{6}$-scale, rocket-powered models of the MX-776 designed and supplied by

the Bell Aircraft Corporation. The models used in the present investigation vary considerably both in fuselage fineness ratio and wing and fin airfoil sections from those used in previous rocket-powered tests of the MX-776 configuration (references 1 and 2). The configurations used in the reference investigations had fuselage fineness ratios of the order of 12 and partial-span ailerons on symmetrical double-wedge airfoils. Results obtained from these investigations showed a reversal of aileron rolling effectiveness at transonic speeds. The models used in the present investigation had a fuselage fineness ratio of 8 with full-span, constant thickness, blunt trailing-edge ailerons on symmetrical-arc airfoils. The purpose of the present investigation is to ascertain the variation of aileron rolling effectiveness and total drag of the latest MX-776 configuration with Mach number at zero angle of attack. Additional models have been constructed to investigate longitudinal and directional stability characteristics.

Three models have been flown with mean aileron deflections of 2.03°, 5.09°, and 14.78°, respectively, and data obtained from coasting, free flight in the Mach number range from approximately 0.5 to 1.2 are presented in this paper.

SYMBOLS

M Mach number

R Reynolds number based on body diameter

$\frac{pb}{2V}$ tip helix angle, radians

p rolling velocity, radians per second

b diameter of circle swept by wing tips, 2.785 feet

V flight-path velocity, feet per second

C_D drag coefficient $\left(\frac{\text{Drag}}{qS_F}\right)$

q dynamic pressure, pounds per square foot $\left(\frac{\rho V^2}{2}\right)$

S_F body frontal area, 0.349 square foot

ρ density, slugs cubic foot

c_r root chord at fuselage center line, inches

c_t tip chord, inches

t_r maximum thickness at fuselage center line, inches

t_t maximum thickness at tip, inches

δ_a average deflection of each aileron measured in the free-stream direction, degrees

$\bar{c}$ mean aerodynamic chord

MODELS

The MX-776 models used in the investigation were designed and supplied by the Bell Aircraft Corporation. The fuselages were made of balsa wood with aluminum castings to serve as mounts for the wings and fins. The nose cones were cast plexiglass and contained spinsonde transmitters (reference 3) used to determine the rate of roll.

A three-view drawing of the model is presented as figure 1. Pertinent general specifications are given in table I, and the model characteristics are given in table II. The areas given in table 1 include the areas obtained by extending all leading and trailing edges to the fuselage center line. Figures 2 and 3 are photographs of one of the models.

Variations of circular-arc airfoil sections were used for the model surfaces. True symmetrical circular-arc airfoils were used for both fins in the vertical plane with maximum thickness ratios varying from 3 percent at the tips to 5.4 percent at the fuselage center line. The forward horizontal wing had a symmetrical circular-arc airfoil ahead of the 75-percent-chord station with straight lines from there to the trailing edge resulting in a section with the trailing-edge thickness equal to one-half of that at the 75-percent-chord location. The maximum thickness ratio varied from 3 percent at the tips to 5.2 percent at the center line. A similar airfoil was used for the rear horizontal wing but this section had constant thickness behind the 75-percent-chord location resulting in a sealed, full-slab control surface, as shown in the section view in figure 1. The results presented in this paper are concerned with the latter surfaces used as ailerons. The maximum thickness ratio of this wing varied from 4 percent at the tips to 6.2 percent at the center line.

A two-stage rocket-propulsion system, consisting of a booster motor in addition to the sustainer motor located inside the model, was used to propel each model to a Mach number of approximately 1.2. The booster delivered 7,300 pounds of thrust for 1.1 seconds, and the sustainer motor developed 1,500 pounds of thrust for 1.0 second. Sustainer firing as well as drag acting on the booster stabilizing fins assured separation of the model from its booster at the end of booster thrust. The data presented in this paper were obtained during the coasting portion of the flight after the propulsion system ceased thrusting.

TESTS

Flight-path velocities were obtained during the tests by a CW Doppler radar set and time histories of the rolling velocity were obtained from the spinsonde radio equipment. Continuous records of elevation angle and range obtained by an NACA modified SCR-584 radar tracking unit permitted the determination of the altitude of the model and the flight-path angle throughout each test. Atmospheric data were procured from radiosonde observations made immediately after each test. The flights were also recorded by movie cameras and observed visually.

Launching of the model-and-booster combinations was accomplished from a rail-type launcher, (see fig. 4).

Construction tolerances prevented the use of exact aileron deflections and, for this reason, aileron deflections were measured on each model prior to flight. Measurements were made near the tip and near the root of each aileron. The average of these two values for one aileron was considered to be its deflection. The average of the deflections so obtained for the left and right ailerons was considered to be the over-all average deflection δ_a for each model.

The models were designed to fly at or near zero angle of attack and the effect of the asymmetry due to the dorsal conduit tunnel was considered to be negligible.

A plot of Reynolds number against Mach number, shown in figure 5, indicates the scale of the tests.

REDUCTION OF DATA

Mach number during the flights was determined by the use of flight-path-velocity data obtained from the Doppler velocimeter, altitude and

flight-path data obtained from the radar tracking unit, and atmospheric data obtained from the radiosonde. Drag coefficients (based on body frontal area) were determined from the differentiation of the curve of flight-path velocity plotted against time and flight-path-angle data.

Aileron rolling-effectiveness data were procured from the spinsonde record which was reduced to rolling velocity against time and was correlated with flight-path velocity and Mach number to allow the presentation of the variation of tip helix angle $pb/2V$ with Mach number.

ACCURACY

In general, the accuracy of the data presented in this paper is estimated to be within the following limits:

$pb/2V$	± 0.001
C_D	± 0.02
M	± 0.01

Model 1 developed a helical flight path at a Mach number of approximately 1.0 and the accuracy of Doppler velocity data is reduced in this case. For this reason, values of Mach number below $M = 1.0$ obtained from model 1 are probably less accurate than indicated but are estimated to be accurate within ±5 percent.

The measured values of $pb/2V$ differed from steady-roll values because the measurement of rolling velocity was made while the rolling velocity was changing. The measured values can be corrected to steady-roll values by a relation involving the moment of inertia about the roll axis, the rolling acceleration, and the damping in roll (see reference 4). Values of damping in roll were estimated for the MX-776 models and the correction was applied to the data presented herein.

RESULTS AND DISCUSSION

Aileron Rolling Effectiveness

The data obtained from the three model flights are presented in figure 6 as a plot of the variation of tip helix angle $pb/2V$ with Mach number. Flight-path velocity was obtained from the Doppler radar unit for a Mach number range from 1.20 to 0.49 for model 1, from 1.19 to 0.70 for model 2, and from 1.14 to 0.60 for model 3. Since model 1 developed a helical flight path at $M = 1.0$ and Doppler flight-path

velocity is less accurate in this case, values of $pb/2V$ for this model at Mach numbers below this speed are represented by a dashed line. An inquiry into the effect of rolling velocity on longitudinal and directional stability in accordance with the criteria presented in reference 5 indicated that model 1 possessed marginal longitudinal stability with the rolling velocity encountered at speeds below a Mach number of 1.0. The presence of a small angle of attack produced by this marginal stability would account for the helical path observed during the latter portion of the flight.

With reference to figure 6, each of the models showed positive control effectiveness throughout the test speed range with an over-all decrease in rolling effectiveness in going from subsonic to supersonic speeds. No tendency toward reversal was indicated.

The ratio of tip helix angle to aileron deflection for each model is plotted in figure 7 as a function of Mach number. The data indicate an approach to linearity at subsonic speeds up to $M = 0.7$. Between Mach numbers of approximately 0.7 and 1.0, the results indicate a fairly large decrease of aileron effectiveness per unit of deflection with increasing aileron deflection. Above a Mach nunber of about 1.0 a return to approximate linearity is indicated.

Drag

The variation of total drag coefficient (based on the body frontal area) with Mach number for the three models is shown in figure 8. No drag values are presented for model 1 below $M = 1.0$ due to the inaccuracy of longitudinal acceleration determined by differentiation of the curve of Doppler flight-path velocity against time obtained from a model flying a helical path at an angle of attack.

Models 2 and 3 indicated approximately constant drag coefficients at Mach numbers below 0.85 followed by a 125-percent rise between $M = 0.85$ and $M = 1.02$ and decreasing drag values from $M = 1.02$ to the maximum test Mach number. The values of drag coefficient obtained from model 1 agree closely with those obtained from model 2. The difference between these two models is probably within the accuracy of the data and should be small compared to the difference between models 2 and 3, since the change in drag coefficient due to a change in aileron deflection should vary as the square of the deflection.

CONCLUSIONS

The results obtained from tests of three rocket-powered, $\frac{1}{6}$-scale models of the Bell MX-776 allowed the following conclusions to be made concerning the variation of aileron rolling effectiveness and total drag with Mach number in the range from approximately 0.5 to 1.2:

1. Positive control effectiveness was present over the Mach number range tested with an over-all decrease in going from subsonic to supersonic speeds. No tendency toward reversal was indicated.

2. The ratio of tip helix angle to aileron deflection indicated a decrease in rolling effectiveness per unit of deflection with increasing deflections in the Mach number range from approximately 0.7 to 1.0.

3. Total drag coefficients increased about 125 percent between Mach numbers of 0.85 and 1.02 and decreased at higher speeds.

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TABLE I

GENERAL SPECIFICATIONS

[Fuselage: over-all length, 64.00 in.; maximum diameter, 8.00 in.]

	Rear horizontal wings	Forward horizontal wings	Rear vertical fins	Forward vertical fins
Aspect ratio	3.05	3.22	3.20	3.70
Total span, in	33.42	22.90	25.00	13.27
Total area, sq ft	2.54	1.13	1.36	0.33
Angle of incidence, deg . . .	0	0	0	0
Dihedral, deg	0	0	0	0
Sweep, 0.75 chord, deg	0	0	0	0
Root chord, at model center line, c_r, in.	17.11	11.36	12.45	6.03
Tip chord, c_t, in.	4.78	2.87	3.19	1.13
Root thickness ratio, t_r/c_r .	0.062	0.052	0.052	0.054
Tip thickness ratio, t_t/c_t . .	0.040	0.030	0.030	0.030
Hinge-line location, percent chord	75.0	-----	-----	-----
Airfoil section	(a)	(b)	(c)	(c)

[a]Symmetrical circular arc with full-slab behind 75-percent chord.
[b]Symmetrical circular arc with half-slab behind 75-percent chord.
[c]Symmetrical circular arc.

TABLE II

MODEL CHARACTERISTICS DURING THE COASTING PORTION OF THE FLIGHTS

[Station numbers correspond to distance in inches from the end of the nose]

Model	Mean aileron deflection (deg)	Weight, (lb)	Center-of-gravity location, station	Moment of inertia (slug-ft^2)	
				Pitch	Roll
1	2.03	88.50	33.9	7.6	0.33
2	5.09	89.06	33.7	7.6	0.33
3	14.78	88.38	34.0	7.6	0.33

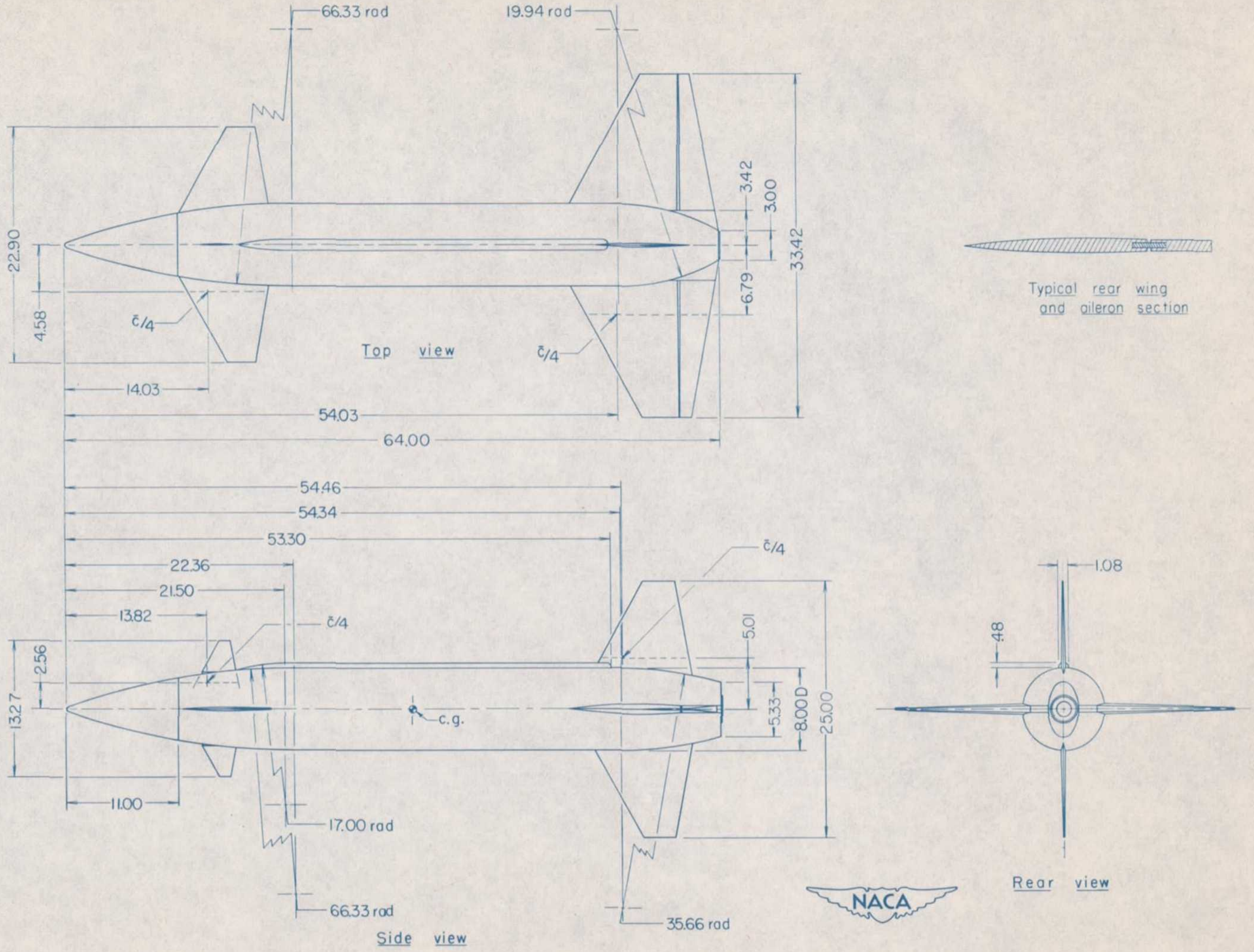

Figure 1.- General arrangement of $\frac{1}{6}$ - scale Bell MX-776 rocket-powered free-flight model. All dimensions are in inches.

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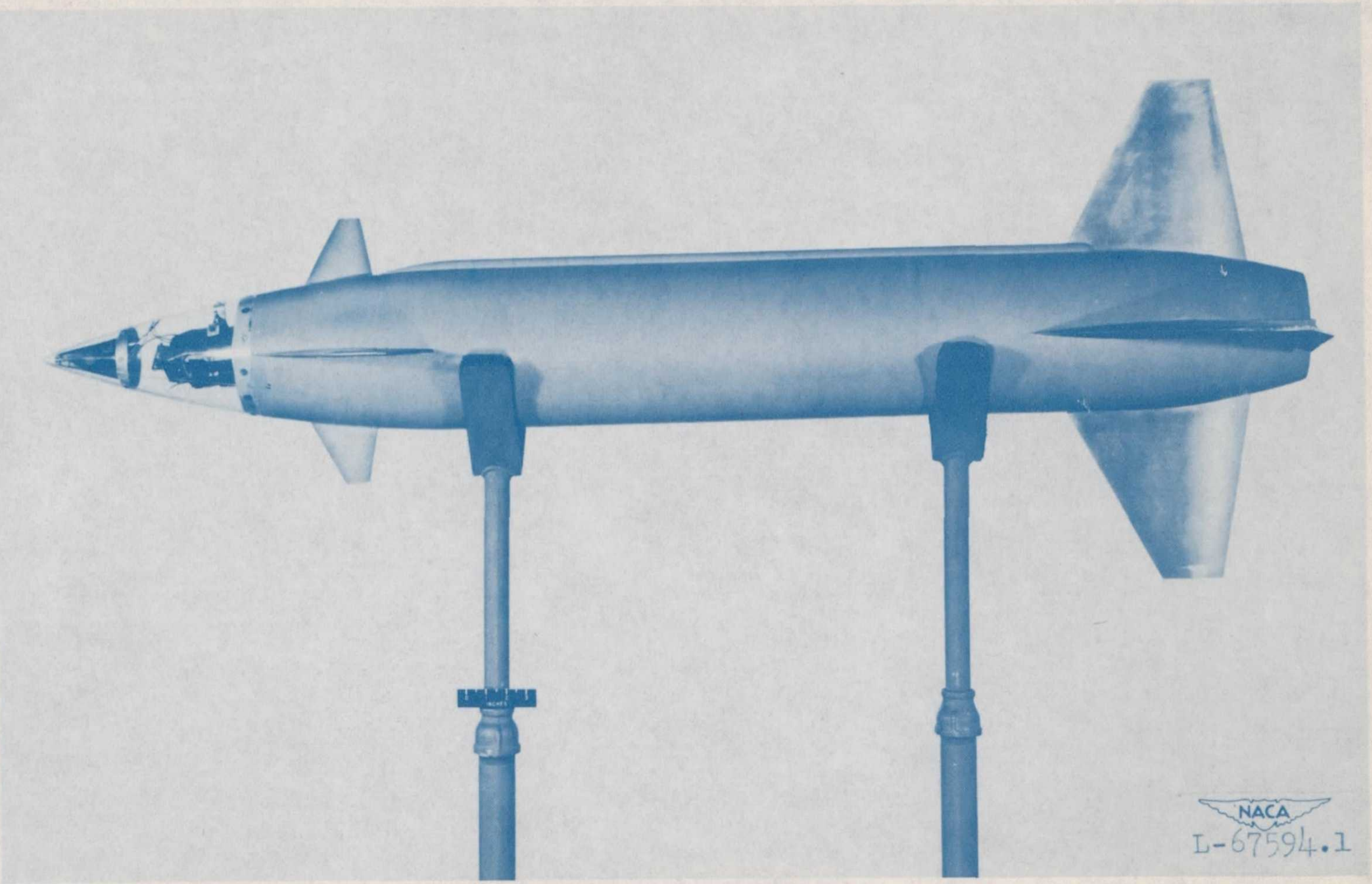

Figure 2.- Side view of Bell MX-776 rocket-powered flight test model.

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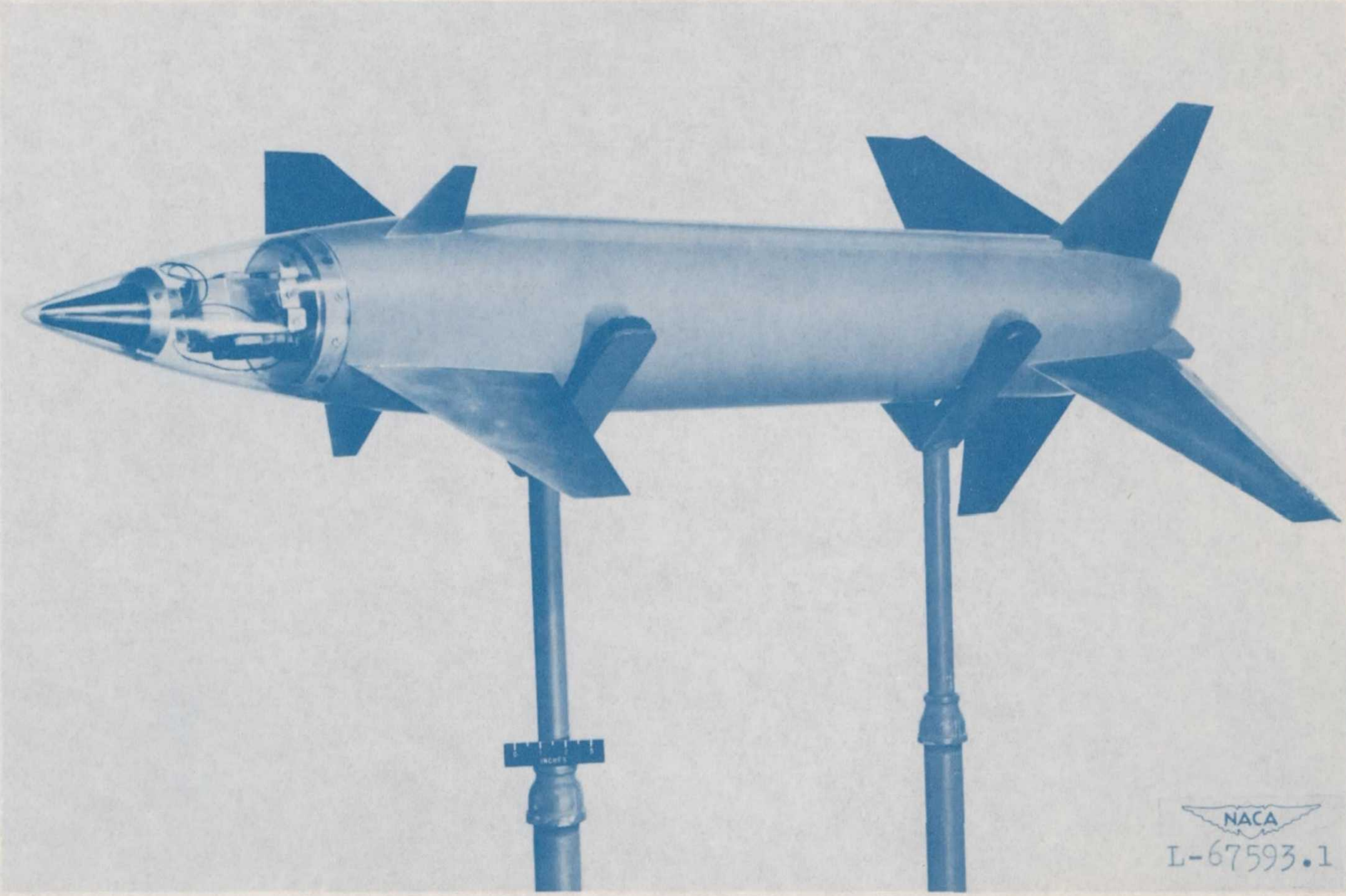

Figure 3.- Three-quarter top view of Bell MX-776 rocket-powered flight test model.

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Figure 4.- Model and booster on rail launcher.

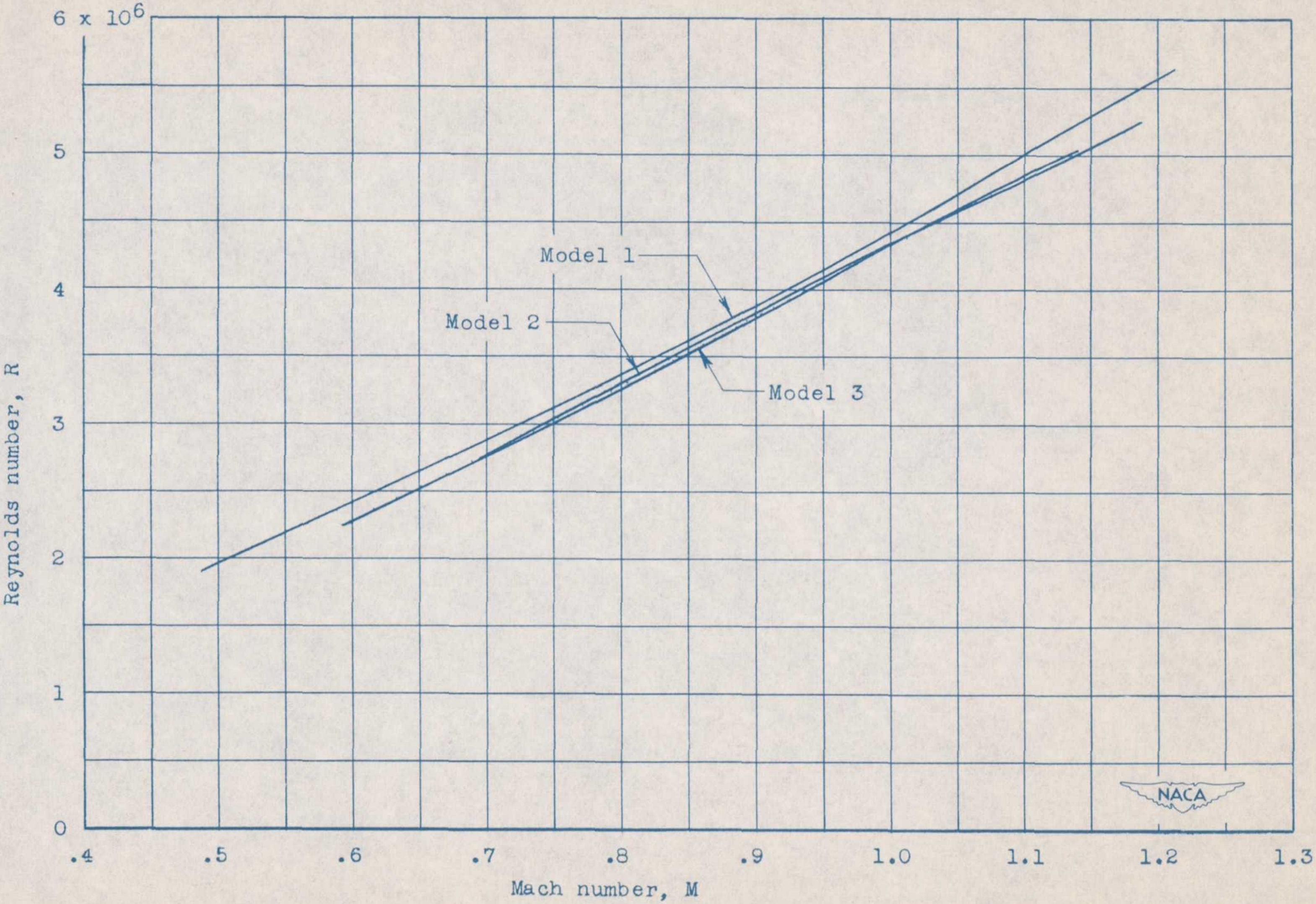

Figure 5.- Variation of Reynolds number based on maximum fuselage diameter with Mach number.

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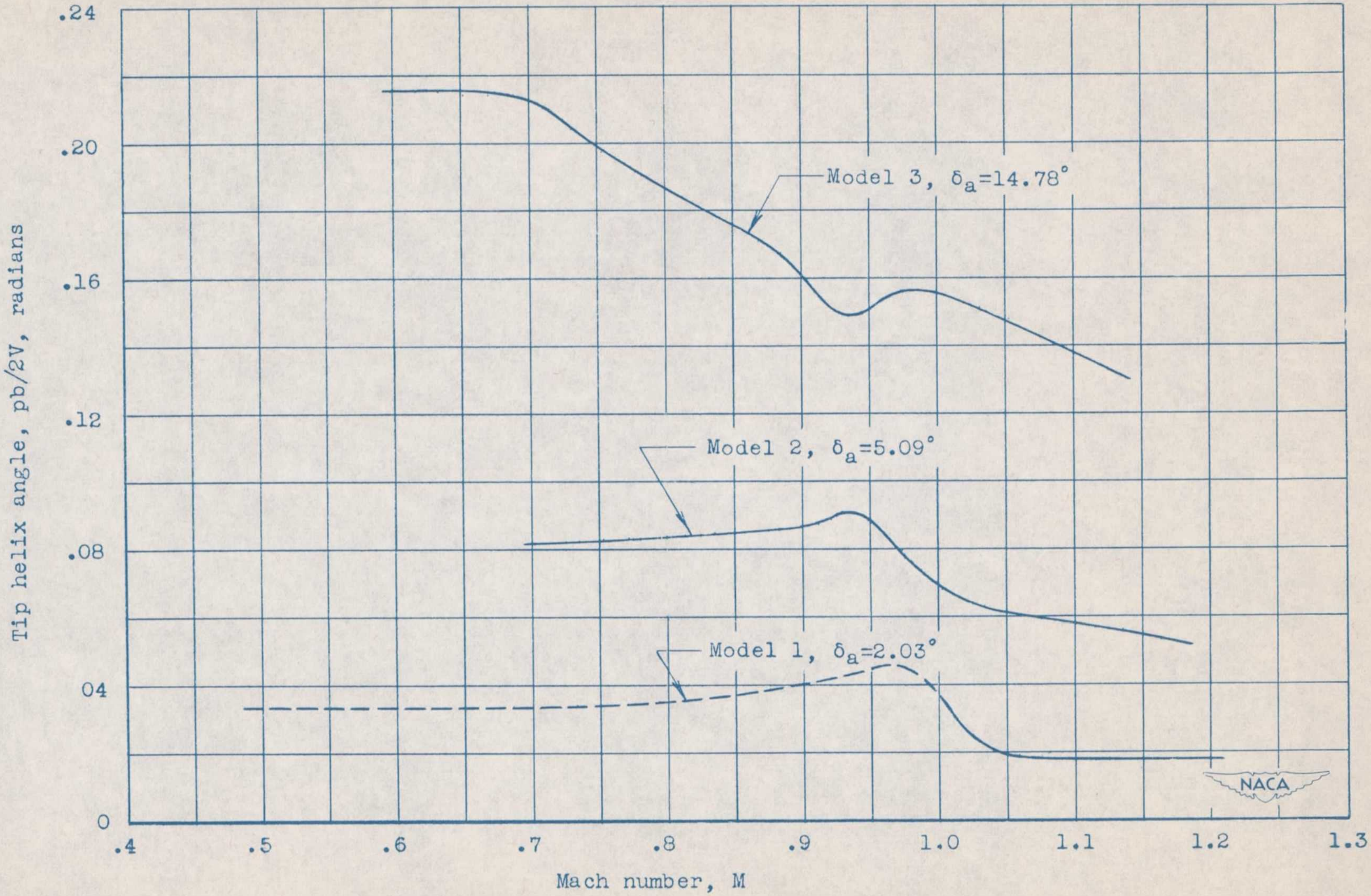

Figure 6.- Variation of tip helix angle with Mach number.

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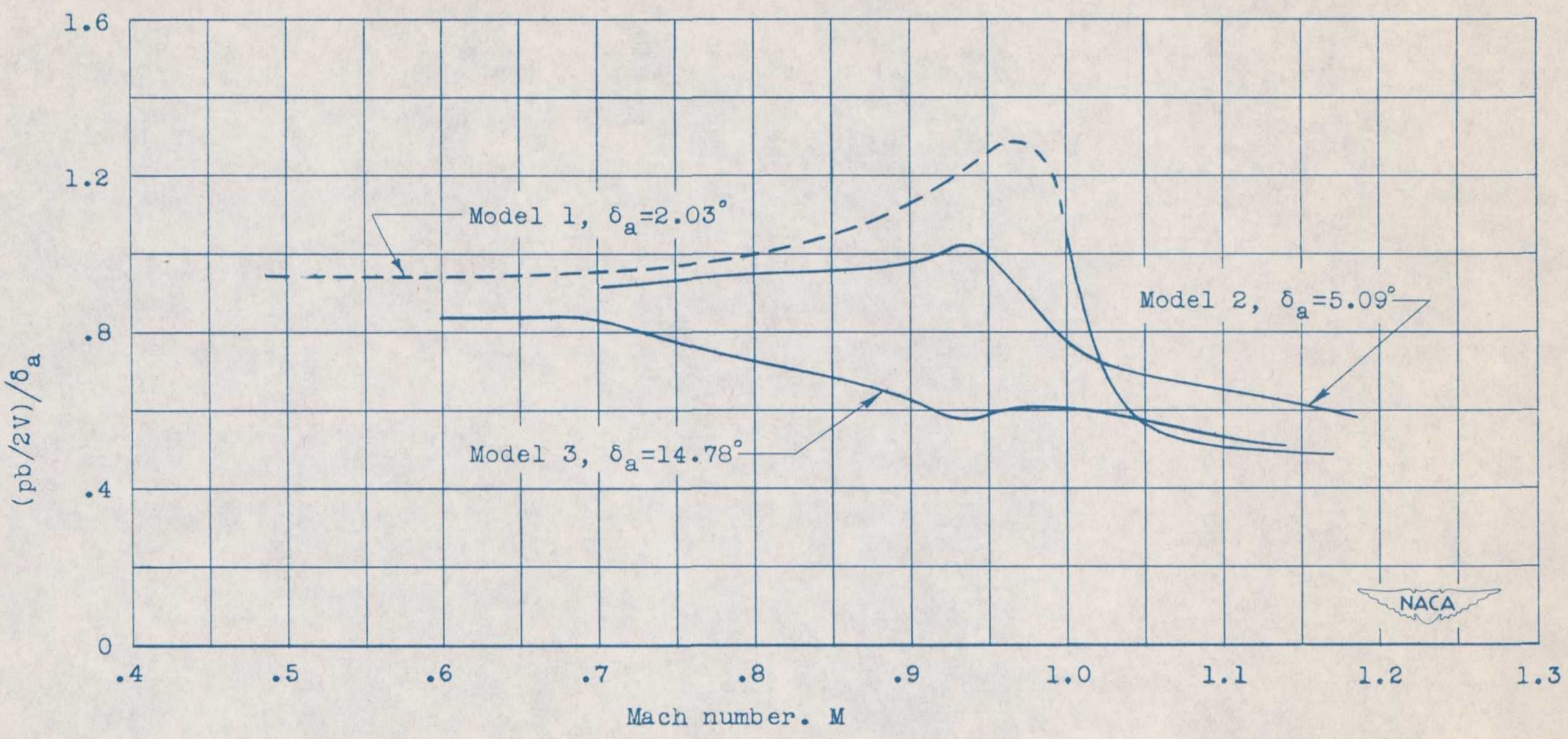

Figure 7.- Variation of the ratio of tip helix angle to aileron deflection with Mach number.

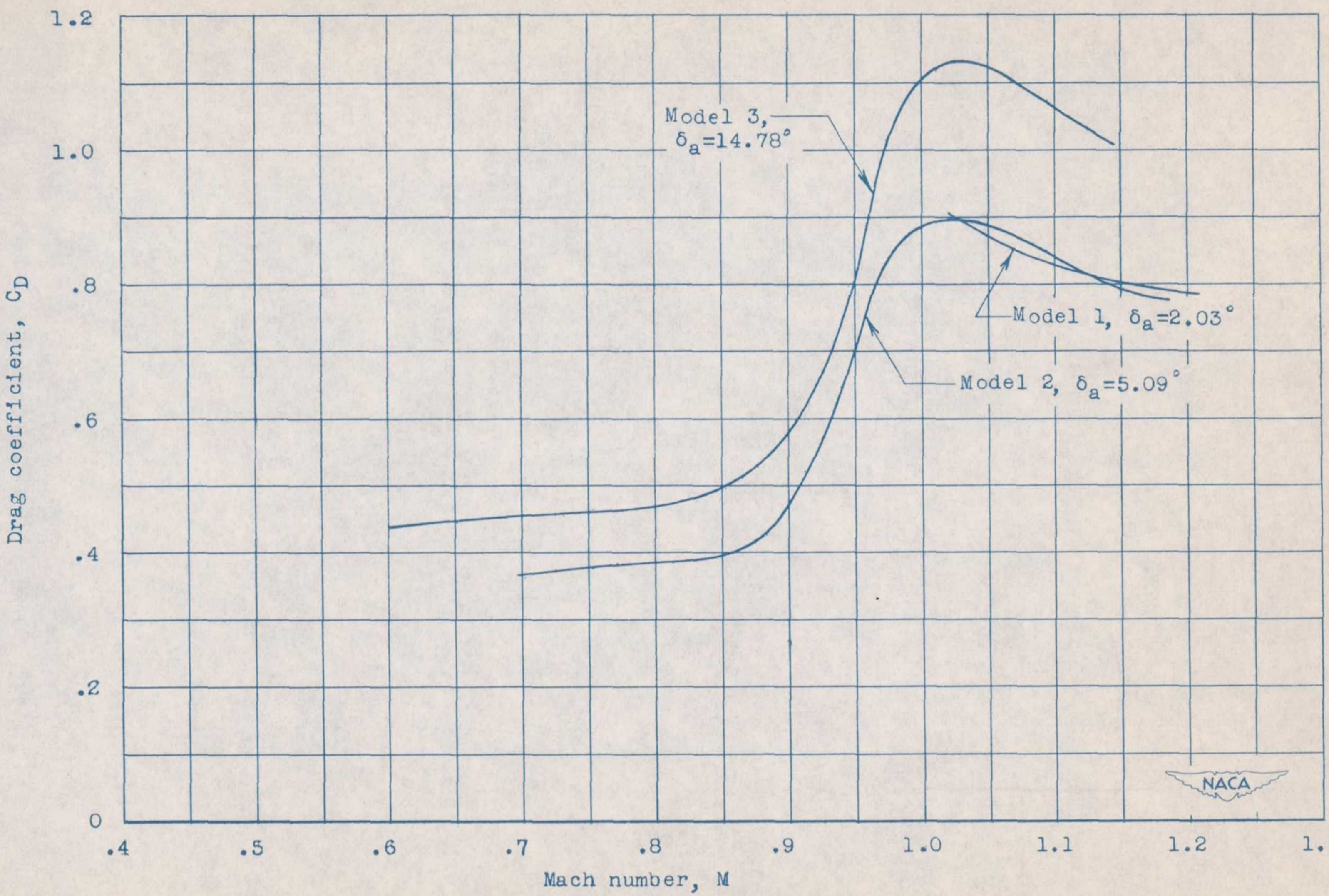

Figure 8.- Variation of total drag coefficient based on body frontal area with Mach number.

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